MINISTRY OF HEALTH

SCOTTISH OFFICE

MINISTRY OF HOUSING AND
LOCAL GOVERNMENT

Reports on Public Health and Medical Subjects
No. 105

The Conduct of the Fluoridation Studies in the United Kingdom and the Results Achieved after Five Years

LONDON
HER MAJESTY'S STATIONERY OFFICE.
1962

CONTENTS

I. INTRODUCTION

Fluoride occurs naturally in almost all water supplies. In different parts of the world the concentration varies from a trace to 14 parts per million or more. The highest natural concentration in Great Britain is about 6 parts per million.

It has been known for many years that there is a correlation between the level of fluoride naturally present in water supplies and the incidence of dental caries. With high levels of fluoride in drinking water, increased resistance to dental decay can be accompanied by noticeable mottling of the dental enamel but not where the level is below 1½ parts per million.

Extensive investigations in the United States have shown that children born and brought up in an area with about 1 part per million of fluoride occurring naturally in the water have up to 60 per cent less dental decay than children brought up in areas where the water has only a trace of fluoride. In addition, where there is this quantity of fluoride, about 30 per cent of children aged 12 to 14 years have completely sound teeth. There is strong evidence too that the benefit persists well into middle age. Other independent investigations in the United Kingdom and in many other countries supported the American findings with a remarkable degree of uniformity.

In 1945 studies were inaugurated in the United States and Canada to find out whether similar results would follow if enough fluoride were added to a water supply to raise the fluoride content to 1 p.p.m. In 1952, on the recommendation of the Medical Research Council made in the light of the results which were being achieved, the British Government sent a mission to the United States of America and Canada to study fluoridation in operation and to advise whether fluoride should be added to the water supplies in the United Kingdom.

The report of the mission, which was published in 1953, stated that the results emerging in the areas in North America where the water was being fluoridated were similar to those where fluoride occurs naturally. There was nothing to suggest that a water to which fluoride had been added was different in its action or had different properties from one containing fluoride naturally derived. The mission found no scientific evidence of danger to health from the prolonged consumption of water containing fluoride in low concentration. In the few instances where mottling of the teeth occurred it was so slight that it could not be recognised without expert examination and could not be regarded as a hazard. They were impressed by the fact that millions of people were living in ordinary good health on waters containing fluoride at levels of 1 p.p.m. or more.

The mission concluded that fluoridation of water supplies was a valuable health measure through its effect in reducing the incidence of dental caries but recommended that in this country fluoride should be added to the water supplies of some selected communities before its general adoption was considered. These preliminary projects should be regarded as study centres and include full medical and dental examinations at all ages. Before these studies were begun it would be necessary to obtain baseline information on the incidence of dental caries in the selected communities and, if possible, in comparable communities which would be used as controls; to assess the amount of fluoride to be added to water supplies in this country; and to make sure that adequate supplies of fluorides in the most suitable form were available and to develop the machinery necessary for the controlled addition of fluorides to water supplies with adequate safeguards.

The mission further recommended that, despite the strong evidence of harm-

lessness, research into the effects on health and disease of the continued use of waters containing low levels of fluoride should be encouraged.

On the advice of the Standing Dental Advisory Committee the Government accepted these recommendations. To design and supervise the conduct of the studies, a steering committee was set up, including officials knowledgeable in the relevant dental, medical, chemical, water supply and statistical matters, drawn from the Ministry of Health, Department of Health for Scotland, Welsh Board of Health, Laboratory of the Government Chemist, Ministry of Housing and Local Government and its Welsh Office and Ministry of Education. The Medical Research Council were also represented and subsequently, after the study areas had been selected, the committee was joined by the medical officers of health and water engineers of the local authorities concerned, and representatives of the Ministry of Health and Local Government of Northern Ireland, the Central Council for Health Education and the British Dental Association.

This report describes the conduct of the fluoridation studies and the results achieved by 1961.

II. PRELIMINARY WORK

(a) *Assessment of Appropriate Level of Fluoride in Water Supplies in Great Britain*

The Mission thought that the appropriate level of fluoride for this country would not differ greatly from that adopted in the United States. Since however British eating and drinking habits differ from those prevalent in America, it was necessary to find out whether there was likely to be any difference in the effect of a level of 1 p.p.m. of fluoride in the water here.

No normal diet is free from fluoride. Most foodstuffs contain a little and some are quite rich in fluoride. But the total amount derived from foodstuffs is comparatively small in relation to the amount which can be obtained from liquids. In particular many teas are rich in fluoride : determinations made in the laboratory of the Government Chemist had showed that medium strength infusions of tea brewed with water containing little or no fluoride contained about 1 p.p.m. of fluoride. The Mission therefore had in mind that while less liquid might be consumed in this country, fluoride might already be given to children in significant amounts in tea. The Mission suggested that whether or not this was so might be checked by a survey of fluoride excretion in the urine. (Studies had suggested that there is a relationship between the amount of fluoride ingested and that excreted in the urine.) A pilot survey of the urine of a sample of children was undertaken, together with a pilot survey of the consumption of liquids by children (and adults.) Details are given in Appendix 1. The results suggested that full scale surveys would be likely to confirm the Mission's preliminary view that the appropriate level of fluoride in this country would not differ greatly from that adopted in America.

Meanwhile the conclusion had been reached that the appropriate level of fluoride in Great Britain could more directly be assessed, as had been done in the United States, by examining the children's teeth in areas where the natural fluoride content of the water supplies was at different levels. The dental survey for this purpose was commenced in 1954 and the results, set out in Appendix 1, showed a relationship between the fluoride content in the water supplies and the dental condition of the children which was in close keeping with American data on the subject.

Accordingly the decision was reached that there was no reason to depart from the level of 1 p.p.m. generally adopted in the fluoridation of water supplies in the United States.

Consideration was given to the possibility that if water supplies were fluoridated to this level for dental protection, adults who were heavy tea drinkers might consume an excess of fluoride. But in the light of reports from America in which inhabitants of Bartlett where the water naturally contained 7 to 8 p.p.m. were compared with those of Cameron where the level of fluoride is 0·4 p.p.m. and of other evidence this hypothesis was judged to be unfounded. This question of the risk of excessive intake of fluoride is dealt with in detail in Appendix 8.

(b) *Survey of Fluoridation Equipment and Chemicals*

At the time fluoridation was contemplated in Great Britain, it had been practised in the United States of America for nearly ten years and the experience gained there was available. There seemed no doubt that fluoride could be

added and maintained at a pre-determined concentration in a public water supply with little more difficulty than that involved in the normal addition of chemicals for the clarification and disinfection of water. Nevertheless a review of the equipment available was undertaken and a note on the result is contained in Appendix 2. This also sets out the considerations underlying the selection of the type of fluoride suitable to be added to water supplies in this country.

Fluoridation studies in the United States have shown that the different inorganic fluorides used in water fluoridation give similar results. This applies not only to sodium fluoride and sodium fluorosilicate but also to calcium fluoride which is probably the main source of fluoride occurring naturally in drinking waters. This is because these salts of fluoride are completely ionised in dilute aqueous solution and their fluoride ions react identically in the chemical sense and, on all the evidence available, also in the physiological sense.

Fluoride ions are present at least in trace amounts in all drinking waters together with sodium, calcium and other ions and of all these, calcium predominates. Thus the fluoridation of drinking water simply increases the concentration of something that is already present ; the qualitative composition of the water is not altered. It would be impossible to differentiate by analysis a water containing fluoride naturally derived from one where fluoride had been added artificially.

III. GENERAL PLAN OF THE STUDIES

(a) *Method*

It was decided to fluoridate the water supply of at least three communities and, in order that it could be seen whether subsequent findings could be attributed to the presence of fluoride, to establish a corresponding " control " area as nearly as possible comparable with each of the areas whose water supply was fluoridated. The studies in each pair of study and control areas were planned so as to form parts of one large study.

(b) *Criteria for the Selection of Study and Control Areas*

The main criteria for the selection of the areas were that (1) the population of each study and control area should be of sufficient size to provide an adequate sample of children and other population groups; (2) the study and its associated control area should be situated near to each other and be of the same character e.g. industrial, semi-industrial, rural or residential; (3) the pairs of study and control areas should be in different parts of the country so that the effect of fluoridation could be assessed in different environmental and dietary conditions; (4) the water supplies of each pair of study and control areas should, if possible, be from the same geological sources and be of the same kind (e.g. soft or hard) and undergo the same kind of chemical treatment at the water works before entering the domestic supply; and (5) the water supplies in the control and study areas should have a negligible natural fluoride content.

(c) *Assessment of Dental Effects*

Drinking of water containing fluoride for a few years during adult life could not be expected to have any appreciable effect. It was therefore decided that the value of fluoridation must, at least in the short run, be assessed from its effect on the teeth of children. Plans were made to examine representative groups of children in the study and control areas shortly before fluoride was added to the water supply in the study areas and at annual intervals subsequently. The results of the examinations were to be recorded in a manner which would permit comparison with data obtained in American surveys.

(d) *Assessment of Safety of Fluoridation*

Like many other substances which are beneficial or even essential to the human body when taken in proper quantities, fluoride can become harmful in excess. Before the Government's decision was taken to proceed with the fluoridation studies in this country, account had been taken of the already substantial volume of research into the safety of fluoridation. Nowhere had any evidence been discovered of danger to health arising from the consumption of water containing fluoride at the level of 1 p.p.m.

By the time the studies were due to begin, a great deal of further evidence on the safety of fluoridation of water at a level of 1 p.p.m. had become available. For example, a study including medical, radiological and laboratory examinations had been performed on long-term residents in Bartlett, Texas, where the the water contained 7-8 p.p.m. fluoride and compared with residents of Cameron where the water contained only 0·4 p.p.m.: the examinations in each case had been repeated after a period of ten years. Results were also available after six years of artificial fluoridation in Newburgh, New York on the medical examina-

tions of children in this and in the control town of Kingston. An extensive analysis of the death rate from major causes of mortality in American cities with high and low levels of fluoride in their water supplies had been reported. All these reports were reassuring in their bearing on the safety of fluoridation of water at a level of 1 p.p.m.

Comparisons made in 1954 of vital statistics in the United Kingdom also showed that between high and low fluoride areas there were no differences in the mortality rates which could be interpreted as indicating any harmful effect on health.

In 1956 a conference of experts convened by the Medical Research Council to advise the Health Departments on what need there might be for further research " agreed in general with the conclusions of the United Kingdom mission to the effect that despite considerable interest and research there is no definite evidence that the continued consumption of fluorides in water at a level of about one part per million in drinking water is in any way harmful to health and that if any untoward effect is revealed by future research it is most unlikely to be serious." They considered that further specific research should be directed towards reasonable hypotheses only: continuous vigilance should however be maintained by all concerned by study of the relevant vital statistics, and specific investigation instituted where indicated.

Full medical examination of persons of all ages in the study areas, as suggested by the mission to North America, was therefore considered unnecessary.

After consultation with the Medical Research Council, a special research committee was set up for the purpose of planning any research which might be thought necessary and assessing the results. This committee included research workers into the physiological, biochemical, toxicological and dental aspects of fluorine, also professional officers drawn from the Ministry of Health and the laboratory of the Government Chemist.

IV. DETAILS OF THE STUDIES

(a) *The Study and Control Areas*

The areas selected for the purposes of the study were Watford in Hertfordshire, part of the county of Anglesey and Kilmarnock in Ayrshire. The local authorities for each of these areas had previously expressed an interest in fluoridation and, on receipt of the Ministers' formal invitation to take part in the studies, agreed to do so. The control arcas selected were Sutton in Surrey, the remainder of the County of Anglesey and the County Town of Ayr respectively. The local authorities concerned agreed to the dental examinations necessary for purposes of comparison being carried out in their areas.

Anglesey is mainly agricultural in character with sòme 50,000 population. Holyhead, the largest town, has a population of about 10,000. The water is soft and the water supply for the whole county except Holyhead comes from one source. There are however two pumping stations one of which serves the Gwalchmai zone and the other the Bodafon zone. Fluoride was added to the water pumped to the Gwalchmai zone but not to that for the Bodafon zone. Holyhead receives most of its water supply from the pumping station serving the Gwalchmai zone but at times of heavy demand needs to take additional supplies from a secondary station. It was not practical to add fluoride to the supply from this secondary station ; consequently the level of fluoride in the water reaching Holyhead has varied according to the extent to which it contained water drawn from the unfluoridated source. In the circumstances the results of the dental examinations carried out in Holyhead have been shown separately.

Watford and Sutton, which have a population of some 70-80,000 are within a few miles of London and are largely residential. The water supplies of both these localities are hard and are softened before distribution.

Kilmarnock and Ayr are mainly industrial localities and have a population of about 43,000. Kilmarnock has two sources of supply in both of which the water is soft. The water supply of Ayr is similar in composition.

Andover in Hampshire with Winchester as its control town was selected as a fourth study area but fluoridation in this area was discontinued by the local authority after two years. Norwich and Darlington, which were invited to become study areas, were unwilling to do so.

(b) *Commencement of Fluoridation in the Study Areas*

After preliminary visits to the study areas to assess the type of equipment to be used, the point in the system where fluoride was to be added and storage requirements for the fluoride chemicals, orders were placed for chemicals and equipment including, if necessary, suitable meters for measuring the volume of water pumped. In addition, the provision of test-sets for determining the concentration of fluoride in the water was arranged. When everything was ready, a team composed of engineers representing the equipment manufacturer, an engineer of the Ministry of Housing and Local Government and scientists from the laboratory of the Government Chemist visited the area and, in collaboration with the local water engineer and the medical officer of health, put the scheme into operation. This included the necessary training of the local staff in the operation of the fluoridators, the storage and handling of and accounting for the chemical, the method of adjusting the feed rates and the chemical determination of the concentration of fluoride in the water.

Fluoridation began in Anglesey on the 17th November, 1955, in Kilmarnock

on the 19th April, 1956, and in Watford on the 15th May, 1956. The concentration of the fluoride was built up gradually in the water and numerous checks were made to ensure that the arrangements were working satisfactorily. Details of the method of fluoridation in each study area, an assessment of the cost and the procedure adopted by waterworks staff are contained in Appendix 3: the way in which control has been exercised over the level of fluoridation is described in Appendix 4 which also contains statistics showing the results of checks taken to test the level of fluoride in the water supply. Throughout the period of the study the equipment as a whole has worked satisfactorily in all the study areas. Such maintenance as has been required has not revealed any serious faults and the variations from day to day in the level of fluoride have been within entirely acceptable limits.

(c) *Dental Examinations*

Dental examinations were commenced in each of the study and control areas in 1955 and have since been repeated at annual intervals. Details of the arrangements for these examinations, including the method of examination and the criteria for the assessment of the dental condition of the children are contained in Appendix 5. Representative groups of children of the ages of 3 and 4 years and of school children of each year of age were examined in each area and as far as possible the same standards of examination were maintained in the pairs of areas for which the dental findings were to be compared.

Since fluoridation began in Anglesey approximately midway between the time the dental examinations were held in 1955 and in 1956, the data used to provide baseline information on the dental condition of children in that area are the mean figures for the two years. In the case of Watford and Sutton, and Kilmarnock and Ayr, where fluoride was not added to the water in the study areas until 1956, the results of dental examinations for that year only have been used for baseline purposes.

V. DENTAL FINDINGS

To be fully effective, fluoride must be absorbed continuously during the whole period of tooth formation and calcification. The teeth must then erupt and be exposed to the risk of caries for a reasonable period before any reliable assessment can be made of the extent of caries prevention. For the few years that fluoridation has been in operation in the study areas, therefore, its full effect can now be observed only in children up to the age of 5, who have had fluoride all their lives. Some improvement might now also be expected in children who have had fluoride from birth or early childhood, but little in older children who have not had the benefit of fluoride in their earlier years while their teeth were being formed. Accordingly, although the dental condition of those children aged 3 to 14 years examined in the study and control areas is on record, the findings for the deciduous teeth of children aged 3 to 7 years only are now presented.

The information recorded at the time of the dental examinations can be presented in a variety of ways: in this report the main criterion used in comparing the dental condition of children in the study and control areas is the average number of teeth per child which are decayed, missing, and filled (d.m.f.) termed hereafter "carious teeth". Supporting criteria are the percentage of children free from caries and the percentage of children with ten or more carious teeth.

The assessment of these findings has been made on the full deciduous dentition, that is on 20 teeth, for children aged 3 and 4 years. For children aged 5 to 7 years, the assessment has been made only on the deciduous canines and molars, that is on 12 teeth, because of the uncertainty arising from the natural shedding of the incisor teeth.

The data showing the effects of fluoridation are those for the base-line years and those for 1961, that is 5½ years after fluoridation began in the Gwalchmai zone of Anglesey and in Holyhead and 5 years after it began in Watford and Kilmarnock. Details are set out in Appendix 6. In the study areas of Watford, Kilmarnock, and the Gwalchmai zone of Anglesey the extent of dental decay, as measured by the average number of carious teeth per child, has been markedly reduced in the younger age groups both absolutely and by comparison with the control areas. The proportion of children free from caries has been substantially increased and the proportion of children with 10 or more carious teeth greatly reduced. There has also been a substantial improvement in the dental condition of the children living in Holyhead although, for reasons explained earlier in this report, the level of fluoride in Holyhead has been variable.

Data for the combined study areas, excluding Holyhead, show that, whereas in 1955/56, prior to fluoridation, children aged 3 years had on average 3·80 carious teeth, the average for this age group in 1961 was 1·29. The corresponding figures for four year old children were 5·39 in 1955/56 and 2·31 in 1961 and, for five year old children, 5·81 in 1955/56 and 2·91 in 1961. Among six and seven year old children, some of whose teeth were already calcified before fluoridation began, caries was reduced though not to the same extent. Thus whereas, prior to fluoridation, children at 6 years of age had on average 6·49 carious teeth, the average for this age group in 1961 was 4·81. The corresponding figures for seven year old children were 7·06 and 6·05, respectively.

These reductions amounted to 66 per cent in the 3 year old children, 57 per cent at 4 years and 50 per cent at 5 years. In children of 6 and 7 years whose teeth had not had the full benefit of fluoride the reductions were 26 per cent and 14 per cent respectively.

Over the period of the study there were reductions in the control areas also but these were of a very different order ranging for children aged 3-7 years from 2 per cent to 7 per cent and cannot be regarded as of any great consequence.

These findings are illustrated by the graph on page 11 which, among other things, shows clearly that the maximum improvement in the dental condition has taken place in children who have had the benefit of fluoride for their whole lives: there has been a smaller improvement among the older children who did not have fluoride in their earlier years.

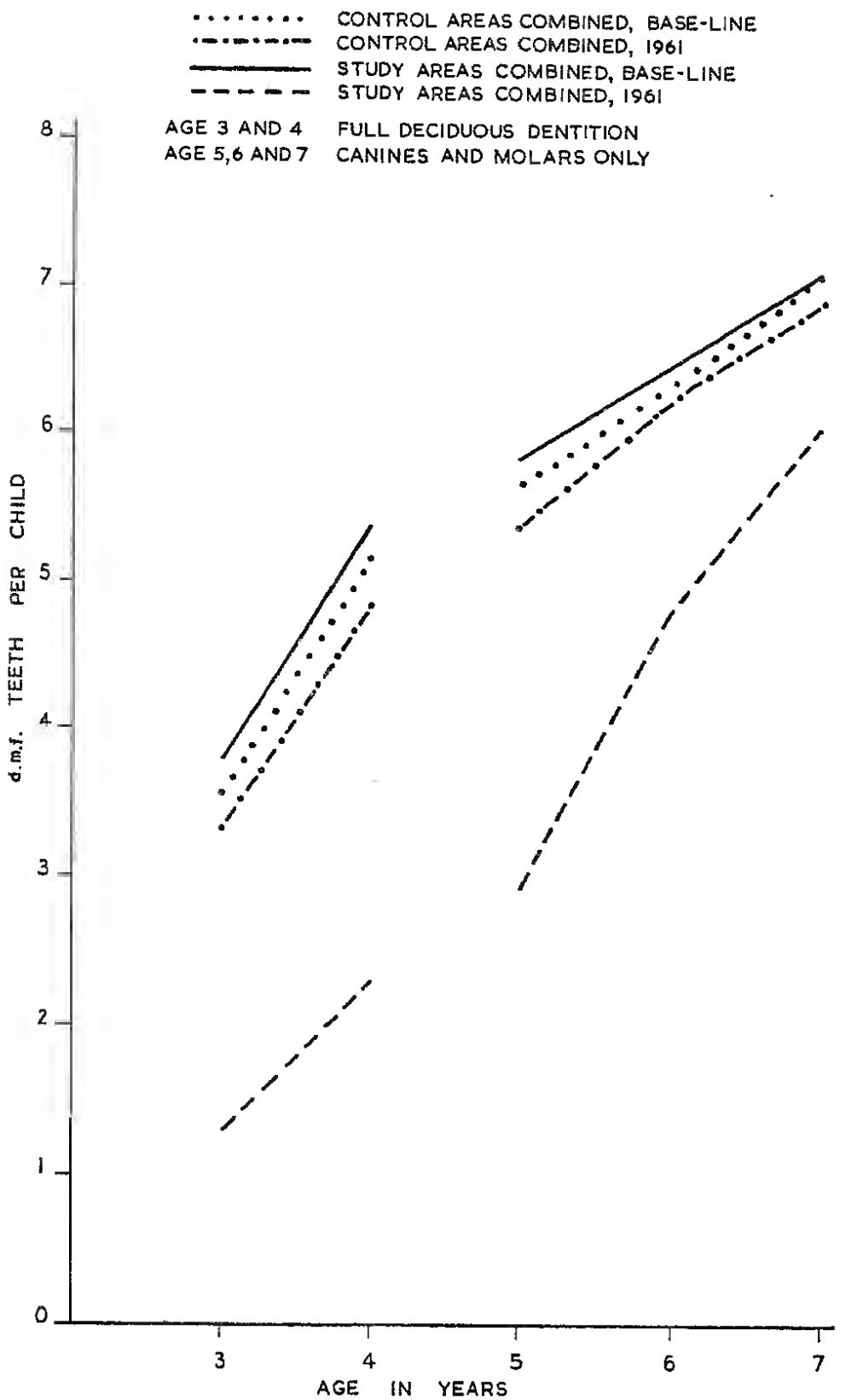
Appendix 6 also shows that, overall, taking into account changes in the control areas, the proportion of children in the study areas free from caries has been increased by about three-quarters. At the age of 3 years, the proportion has risen from 32 per cent to 60 per cent, at the age of 4 years, from 22 per cent to 42 per cent and the improvement among the older children is of much the same order.

Further, the proportion of children in the study areas with ten or more carious teeth has been reduced by as much as six-sevenths in the case of children aged 3 and 4 years. At the age of three, the proportion has gone down from about 15 per cent to 2 per cent and at the age of 4 years from 21 per cent to 4 per cent. Smaller reductions have taken place in the case of the older children.

Thus fluoridation has brought about a substantial improvement in the dental condition of the deciduous teeth of children in the study areas. The results for children aged 4 and 5 years, which alone can be compared with American results, appear to be in line with them (see Table 5 of Appendix 6).

There is good reason to expect that the longer term effects of fluoridation will be similar to the American. The tables in Appendix 7 illustrate the results achieved in three North American studies after 9 years or more of fluoridation. These results relate to the permanent dentition and show that among children up to ten years of age who have had fluoride for the whole of their lives, caries was reduced by more than 50 per cent and that the incidence of caries in these age groups reached about the same low level as in an area where fluoride occurs naturally at the same concentration.

THE INCIDENCE OF CARIES IN STUDY AND CONTROL AREAS. BASE-LINE COMPARED WITH 1961



Note.—Full effect of fluoridation can be expected only in those who have had fluoride all their lives, i.e. up to five years of age.

VI. SAFETY OF FLUORIDATION

The Research Committee reviewed the research work already begun or proposed to be carried out by the Steering Committee and, in the context of the array of evidence from other countries, notably the United States, considered the further work required.

Three main lines of approach were adopted: (1) through general practitioners practising in the three study areas, (2) by analysis of vital statistics and, (3) by means of investigations carried out on samples of sections of the public in areas with different levels of fluoride in the water supply to test specific hypotheses or allegations of harm. The report in Appendix 8 represents the statement of the findings of the Research Committee on the safety of fluoridation for the period covered by this report.

In summary, no information has been received from doctors practising in the study areas indicating harm arising out of fluoridation; comparisons of the vital statistics for pairs of high and low fluoride areas in this country show a close correspondence between total mortality from all causes and that such differences as appeared in the death rates from particular causes do not indicate any effect of fluoride and in none of the special investigations undertaken to test specific hypotheses has evidence arisen of any harmful effect.

The Research Committee have therefore reached the conclusion that no harmful effects from the addition of 1 p.p.m. fluoride to drinking water have been demonstrated in any of the extensive medical evidence which they collected and reviewed. In their opinion the general raising of the fluoride content in drinking water to this level is safe.

These conclusions are supported by those reached following independent investigations made outside this country. For instance, in 1958 an Expert Committee on Water Fluoridation set up by the World Health Organisation concluded that the "effectiveness, safety and practicability of fluoridation as a caries-preventive measure has been established". Similar conclusions were reached by independent committees in other countries notably New Zealand, Canada and the Republic of Ireland.

VII. CONCLUSIONS

1. Five years of fluoridation at a level of 1 p.p.m. in three study areas has brought about in each a substantial improvement in the teeth of young children.

2. The results of fluoridation obtained so far are in line with American experience.

3. No evidence of harm from fluoridation has been discerned despite continuous vigilance.

4. The addition of fluoride to water supplies at a specified level has presented no technical difficulties.

APPENDIX 1

(a) Dental Survey in the Natural Fluoride Areas in Great Britain

In 1954 a study was undertaken to correlate the incidence of caries and mottling of the teeth with different levels of fluoride and from it to determine the concentration of the fluoride ion in water which would give the maximum protection against dental caries without giving rise to any objectionable effect of mottling or staining.

Four areas in which fluoride was naturally present in the water supplies were selected: West Mersea, Burnham-on-Crouch and Harwich in the County of Essex and Slough in Buckinghamshire. West Mersea has the highest known fluoride content in this country (5·8 p.p.m.). Burnham-on-Crouch, a nearby town, has 3·5 p.p.m. : in Harwich the fluoride level averaged 2·0 p.p.m. until recently and Slough has 0·9 p.p.m.

Saffron Walden and district in Essex and Stoneleigh and Malden West in Surrey were chosen for comparison with these fluoride areas as their water supplies contained no more than a trace of fluoride and the school populations were similar in character.

The groups studied consisted of 324 children aged 12 to 14 years in the fluoride areas and of 259 children in the same age-range in the "non-fluoride" areas. All children had lived continuously from birth in the districts in which they were examined.

The children's teeth were examined in detail and carious lesions, fillings and enamel defects were recorded, exactly as they occurred, on pictorial charts, different colours being used to distinguish between white opacities and stained areas.

To estimate the incidence of caries in the various groups the DMF index was used, that is the average number of decayed, missing (due to caries) and filled teeth per child.

In the "non-fluoride" areas the incidence of caries was 6.6/6.1 DMF teeth per child, and only 4-8 per cent were caries-free.

In Slough, with 0·9 p.p.m.F, the incidence of caries was as low as 2·6 DMF teeth per child; 30 per cent. of the children were entirely free from caries; and mottling of the teeth was negligible.

In Harwich, with 2·0 p.p.m.F., the incidence of caries fell still more to 1·5 DMF teeth per child but mottling of the teeth began to be noticeable in about one in eight of the children examined.

The results ([1]) resembled those in the United States ([2]) where it has been found that the level at which the maximum reduction in caries occurred without causing mottling, was about 1·0 p.p.m.

REFERENCES

1. Forrest, J. R. (1956) *Brit. dent. J.* 100, 8. 195.
2. Dean, H. T. *et al.* (1942). Publ. Hlth Rep. 57, 1155.
3. Dean, H. T. and Arnold, F. A. (1943). J. Amer. Dent. Assoc. 30, 1278.
4. Hodge, H. C. (1950) *J. Amer.* dent. *Assoc.* 40, 436.

(b) Fluoride Intake from the diet

It would be impossible to provide a normal diet that was free from fluoride. Most foodstuffs contain a little and some are quite rich in fluoride. Such commodities as milk, meat, eggs and potatoes contain small amounts up to 0·4 p.p.m. but canned fish has anything from 4·0 to 12·0 p.p.m.F. and other foods such as cheese and chicken about 1·5 p.p.m.F.

An important difference between the United States and this country lies in our habit of drinking tea. Longwell[1] has published data on the consumption of liquids including tea, as shown in Table 1.

Table 1. *Consumption of liquids in Great Britain*

	Average c.c. per day						
	Water	Milk	Beer or Cider	Tea	Coffee Cocoa	Soft Drinks	Total
Men	100	414	230	1,100	71	29	1,944
Women	86	386	29	843	57	14	1,415
Children 5–14 years ..	200	443	—	286	14	86	1,029

From these and other data the average intakes of fluoride by adults of both sexes and by children, both with and without fluoride in their water supplies were calculated.

Table 2. *Average intake of Fluoride Mg.F. per day*

	Water containing no fluoride	Fluoridated Water 1 p.p.m.F.
Men	1·8	3·2
Women	1·3	2·2
Children 5-14 years	0·6	1·2

The total intake for children 5 to 14 years old, is similar to that given by McClure[2] for American children and suggests that fluoridation to the level of 1 p.p.m. in Britain would provide effects upon teeth similar to those obtained in America, as in fact is indicated in Appendix 1(a). The adult who is a heavy tea drinker will have a higher fluoride intake but it would require the consumption of about 1 gallon of a moderate strength tea made with fluoridated water to raise the intake to even the average of adults residing in Bartlett, Texas who have been the subject of a medical examination which is discussed in Appendix 8.

Excretion of Fluoride

Absorbed fluoride is excreted mainly in the urine and McClure[3] found that at levels of intake of about 3 mg.F. per day, 80 per cent was excreted in urine, some was lost in perspiration and faeces and only a small proportion was retained in the body. Largent[4] in one experiment lasting over a period of 45 weeks, when a subject was given 3·1 mg.F. per day, found in the first four weeks that 63 per cent of the daily intake was excreted in the urine and during the final eight weeks about 85 per cent. Studies carried out in the United Kingdom have shown that the rate of urinary excretions of fluoride in two youths of 18 years of age on a diet without tea was between 0·2 to 0·6 mg.F. per day. The daily output of urinary fluoride showed an immediate increase when the diet was altered to include 1,200 c.c. of tea or water containing 1 p.p.m.F. but a period of 7 days was required to attain an equilibrium between the intake and output of fluoride. The amount excreted in the urine steadied at about 80 per cent of the intake which with fluoride eliminated in the faeces and perspiration accounted for about 95 per cent of the total intake.

In a further study in this country the urine of 36 children in an area where the water contained virtually no fluoride was collected over a period of 24 hours.

Table 3. *Urinary excretion of fluoride by children*

Age	Average (mg. per 24 hours)	Range (mg.)
5–6 years	0·16	0·07–0·27
8–9 years	0·22	0·10–0·36
11–12 years ..	0·35	0·17–0·67

The average urinary excretion of 0·35 mg.F. of the 11-12 year age group, when compared with the lower corresponding figures for the two younger age groups, probably indicates a higher consumption of tea by the former. Similarly the figure given in Table 1 of 286 c.c. as the average daily consumption of tea by children aged 5-14 masks the fact that tea is drunk to a much larger extent by older children than by younger ones. Urinary excretion of fluoride by the lower age groups was so small that tea cannot play an important part in diets in this country during the period of tooth calcification: and this was the possibility which the U.K. mission to North America wished to assess.

The findings of these enquiries thus support those of the dental survey described in Appendix I(a), which showed that quantitatively the affects of fluoride on teeth are similar in this country and in North America.

REFERENCES

1. Longwell, J. (1957) *Roy. Soc. Hlth. J.* **77**, 361.
2. McClure F. J. (1943) *Amer. J. Dis. Child.*, **66**, 362.
3. McClure F. J. (1945) *J. indust. Hyg. and Toxicol.*, **27**, 159.
4. Largent F. (1954) *Metabolism of inorganic fluorides.* In *Fluoridation as a public health measure*, American Association for the Advancement of Science, Washington. p. 49.

APPENDIX 2

Note on the Survey of Fluoridation Equipment and Chemicals

I. Equipment

The review of the fluoridation equipment available showed that little improvement could be suggested for the type of feeder suitable for large supplies but that the position was not so satisfactory for those supplies where the water pumping rate did not exceed about 70,000 gallons per hour (g.p.h.).

In fluoridation of such supplies it was usual to make batch solutions of a soluble fluoride, sodium fluoride, and proportion this solution to the water in accordance with the rate of pumping. The preparation of an accurate solution rested upon the individual and necessitated an attention to detail which would have been burdensome. A saturated solution of sodium fluoride contains 4 per cent by weight of the salt over a wide range of temperature and use was made of this fact in the design of a continuous flow sodium fluoride saturator by Messrs. Wallace and Tiernan working in collaboration with staff of the Government Chemist. This saturator has been described;([1]) it consists of a chamber in the lower part of which an excess of sodium fluoride, approximately 10 per cent over that required to make a saturated solution, is mixed by means of a circulating pump with base-exchange softened water. As this solution is withdrawn from the chamber it passes upwards through a series of perforated baffles which break the turbulence and give a clear supernatant solution in the chamber above the baffles. A photo-electric cell measures the turbidity of this supernatant solution and automatically cuts off the circulating pump if any undissolved sodium fluoride reaches the clear well. The clear solution of constant strength sodium fluoride is pumped into supply by means of a chemical pump, accurately calibrated, and is replaced by fresh water, the level of liquid in the saturator being maintained by a ball float.

Sodium fluoride in solid form is added to the saturator two or three times a day in quantity sufficient to compensate for the sodium fluoride withdrawn in the saturator solution.

The presence of calcium in the water supply does not matter when fluoride is present at a concentration of 1 part per million (p.p.m.) fluoride as any calcium fluoride formed would be well within its solubility. In the saturator, however, the concentration of fluoride is of the order of 4 per cent and calcium fluoride would be precipitated. To prevent this, all water entering the saturator is base-exchange softened and is measured by passing it through a calibrated tipping bucket, the number of tips being registered by an electrical counter.

The type of equipment chosen for use where the pumping rate exceeded 70,000 g.p.h. was a volumetric feeder of American design which had proved very satisfactory in America. A volumetric feeder delivers a measured volume of the solid chemical in unit time into a continuous flow dissolving tank. The volume of water used in the dissolving tank is immaterial so long as it is sufficient to dissolve the fluoride. The resulting solution passes continuously into supply either by gravity flow or using a pump. The water supply is measured by a venturi type meter which imparts an impulse to the feeder to control the rate of feed of dry chemical in accordance with the rate of pumping. Safety devices are incorporated in the feeder which give warning of any departure

1. Longwell, J. (1957) *Roy. Soc. Hlth. J.*, 77, 361.

from the pre-determined rate of dosing. The feeders are fitted with recorders which register, on a permanent chart, the weight of chemical remaining in the feeding hopper at all times and from this the weight of chemical used in unit time is ascertained. The amount of water pumped during the same period of time is also recorded and thus the concentration that should be present in the water can be calculated.

II. Fluoride Chemicals

In America a variety of fluorides are used in water fluoridation but in this country for the purposes of the fluoridation studies, they were restricted to two.

Several factors influenced the choice, solubility, availability and cost being the chief. For the small supplies pumping less than 70,000 g.p.h. the use of a soluble fluoride salt was necessary. For such supplies in America fluosilicic acid is sometimes used. The commercial acid contains about 30 per cent H_2SiF_6 and is very corrosive to metals although apparently it does not affect skin or clothing. It seemed better in the interests of accurate dosing to add a solution of a relatively low strength than one such as fluorosilicic acid. For these reasons sodium fluoride which can be obtained in a high degree of purity in this country was chosen and the continuous flow saturator developed.

But sodium fluoride is more expensive than sodium fluorosilicate and as maximum solubility is not a determining factor for dry feeders it was decided to use sodium fluorosilicate with the volumetric feeders serving the larger water supplies. The fluorosilicate has an additional advantage in that it requires less storage space than does an equivalent amount of sodium fluoride and, since calcium fluorosilicate is more soluble than calcium fluoride, it tends to give less incrustation trouble in the feeder if the solution water is incompletely softened. It is important that a chemical that is fed into a hopper should have definite characteristics as regards moisture content, size of grain particles, etc. if its flow properties are to be suitable. A suitable grade of sodium fluorosilicate was obtained and its supply has been maintained throughout the period under review.

The source of naturally occurring fluoride in water is probably calcium fluoride (fluorspar) and as this is also the cheapest fluoride salt its use as a fluoridating agent would be attractive. It is unfortunate that its low solubility in water—16 to 17 p.p.m. at temperatures of about 65° to 80° F—precludes its use. Maier,[1] however makes use of its solubility in solutions of aluminium compounds to suggest that where the raw water is treated with a coagulant alum, to remove colour etc. a solution of any desired strength of fluoride, from fluorspar can be obtained by varying the concentration of alum in solution. Even so the rate of solution of the salt is slow and vigorous stirring must be maintained during the dissolving period. The method has not yet been sufficiently tested to consider replacing existing procedures having regard to the fact that the only advantage would be the low cost of calcium fluoride. In water at the level of 1 p.p.m.F it would be ionised and like sodium fluoride or sodium fluorosilicate yield F^- ions with identical physiological effects.

1. Maier, F. J., (1960) *J. Amer. Wat. Wks. Ass.* **52**, 197.

APPENDIX 3

Method of Fluoridation in Each of the Study Areas

Anglesey

The Anglesey water is soft and treatment consists of decolorisation by flocculation with alumina ferric and sodium aluminate, chlorine also being added. The water is filtered, pH adjusted with lime, treated with ozone and a further dose of chlorine. Since fluorides are lost by absorption on "flocks" formed in the decolorisation process, the point of addition of fluoride was subsequent to this and coincident with the further chlorination, at a point where rapid and complete mixing would take place.

The standard continuous saturator with a capacity of 95 gallons was not in production when fluoridation commenced in the Gwalchmai zone in Anglesey on 17th November, 1955, but a prototype of 45 gallon capacity was used.

The rate of pumping was 62,000 g.p.h. and, to begin with, one solution pump was switched on. The intended initial concentration of 0·6 p.p.m. F in the water at the Cefni waterworks was reached two hours after the switch on but at Llangefni, about three miles distant, it was not until the next day that an increase of fluoride occurred and the concentration of 0·6 p.p.m. F was not reached until the day after; at more outlying points several days were required to reach this concentration of fluoride. On 18th November the second solution pump was switched on to bring the level of added fluoride to the level of 0·9 p.p.m. F.

The prototype saturator was replaced by the standard model of 95 gallon capacity in March 1956.

Kilmarnock

There are two sources of supply in Kilmarnock, one at North Craig and the other at Amlaird. The North Craig water works provides slow-sand filtration followed by chlorination and the flow, by gravity, varies between 47 and 50 thousand g.p.h. The water is soft and the fluoride was added at the same point as chlorine where good mixing would be obtained. A sodium fluoride saturator was used.

The Amlaird plant provides about 3·5 million gallons per day with a pumping rate of about 146,000 g.p.h. and a volumetric feeder adding sodium fluorosilicate was used. This type of feeder is described in Appendix 2.

The Amlaird water being collected from moorland is coloured and the colour is removed by coagulation followed by filtration. Chlorine is then added and this point was also suitable for the addition of the fluoride by gravity feed.

Fluoridation of the North Craig supply began on the 19th April, 1956, and of the Amlaird supply on the following day but it was three to four days before the level of 0·9 to 1·0 p.p.m. F was reached in the distribution system.

Watford

There are two sources of supply, the smaller at Watford Fields with a pumping rate of about 75,000 g.p.h., and the larger at The Grove pumping between 66 and 132 thousand g.p.h. The Watford Fields supply is lime-softened and a sodium fluoride saturator and solution pumps were used, the injection point of the fluoride being after softening and into the high pressure delivery main

to the reservoir. The Grove supply was a hard water for the first year of fluoridation but base-exchange softening was introduced in May, 1957. For this supply a volumetric solid feeder fitted with automatic control to adjust the rate of chemical feed to the amount of water pumped was installed. The chemical used was sodium fluorosilicate and the solution from the feeder was delivered to supply by an injector operated by the pressure available from the high lift pump delivery main. The point of injection of fluoride at this station was before the base-exchange softening plant, and a series of tests were carried out which established that there was no loss of fluoride resulting from the base-exchange treatment, thus bearing out laboratory findings both in this country and in America.

Fluoridation began on 15th May, 1956, but it was six to eight days before the level of fluoride in the distribution system built up to 0·9 p.p.m. during the daytime when water from The Grove pumping station is pumped direct into supply. This station is connected to a 4 million gallon service reservoir by a common pumping and delivery main, the reservoir being drawn down during the day to meet peak loads and being made up at night when demand falls off. The turnover in the reservoir is thus slow and the required concentration of fluoride was not reached and stabilised in the reservoir water until the middle of June, 1956.

Cost of Fluoridation

Experience gained in the study areas shows that the cost of fluoridation is about 10d. per annum per head of the population supplied.

Personal Precautions taken by Waterworks Staff

Each operator wears gloves whenever he handles fluorides. These gloves are washed after use and stored in a suitable cupboard. He also wears a simple type of respirator to prevent dust from reaching his mouth and nostrils. This is a precaution against an accidental mishap because with careful handling little or no chemical dust is produced.

If fluoride was ingested by the personnel at waterworks handling fluoride chemicals, it would appear in their urine and could be chemically determined. Urine samples from a number of operators were examined at different times and the concentrations of fluoride found varied from 0·8 to 2·3 p.p.m. F. These figures are quite normal and show that there had been no undue intake of fluoride.

APPENDIX 4

Control of the Level of Fluoride in the Water Supplies of the Study Areas

The control of the level of fluoridation was twofold:

1. Records were maintained of the amount of chemical used to fluoridate a definite volume of water. In the case of the saturator the strength of the sodium fluoride solution, which remained constant, was determined by a hydrometer and the volume used was recorded. With the solid feeders, the loss in weight of the fluorosilicate in the feed hopper was recorded. In both cases the volume of water pumped or passing into supply by gravity was measured and from these figures the concentration of fluoride added to the water was calculated. In addition physical checks of the fluoride chemicals, which were stored separately from other chemicals used at the waterworks, were made.
2. Chemical determinations were made of the concentration of fluoride in the finished water.

Tests were carried out each day on samples taken at the waterworks and on samples taken from different points in the distribution service, so arranged as to cover the whole system over a period of time.

A simple colorimetric test was developed which could be carried out by the plant operators at the waterworks after a short training and the day-to-day tests were carried out by this staff.

In addition to these tests, further samples were drawn by the Medical Officer of Health and forwarded to the laboratory of the Government Chemist for repeat determinations. The colorimetric test as used at the waterworks, which depends on the reaction of zirconium and alizarin to produce a lake which is decolorised in proportion to the amount of fluoride ion in the water, was used by the laboratory but, in addition, the samples were checked by a method involving distillation from perchloric acid. This modification eliminates other ions which, if present, might affect the accuracy of the direct colorimetric method. In fact results by both methods were in good agreement, the waters under examination being essentially free from interfering ions.

A daily entry was made on a log sheet by each pumping station showing the volume of water pumped, the amount of fluoride added, the calculated concentration of fluoride in the finished water, the results of the chemical determinations made locally and those made by the laboratory of the Government Chemist.

Each month copies of the complete log sheet were forwarded to the Ministry of Health, the Ministry of Housing and Local Government, the Welsh Board of Health (for Anglesey) or the Department of Health for Scotland, in the case of Kilmarnock. A copy was also sent to the laboratory of the Government Chemist, where the figures were examined to ensure that the methods used were operating satisfactorily.

Table 1 below summarizes results for the first five years.

Table 1

Daily Concentration of Fluoride ion in the Water

(a) Calculated (b) Determined

	Period	Number of Samples	Mean concentration, p.p.m.F. (brackets show standard deviation)	
			(a) calculated *	(b) determined
Anglesey (Gwalchmai)	17th May, 1956 to 31st May, 1961		0·9 (0·11)	
Plant tap		1,773	—	0·98 (0·08)
Distribution system		3,215	—	0·97 (0·09)
Check analyses at L.G.C.		243	—	0·92 (0·14)
Kilmarnock	25th April, 1956 to 31st May, 1961		0·95 (0·13)	
Plant tap		3,590	—	0·94 (0·10)
Distribution system		3,147	—	0·96 (0·10)
Check analyses at L.G.C.		327	—	0·92 (0·12)
Watford	1st Feb. 1957 to 31st May, 1961		0·95 (0·10)	
Plant tap		3,272	—	0·95 (0·07)
Distribution system		5,813	—	0·92 (0·07)
Check analyses at L.G.C.		447	—	0·92 (0·10)

* In the calculated figures no account has been taken of fluoride naturally present which can vary from a mere trace to 0·1 p.p.m.

The concentrations of the fluoride ion have been given to two places of decimals but it should be realised that the accuracy of the chemical determination is not greater than 0·05 p.p.m. F. In fact figures were reported to the nearest 0·1 p.p.m. F. It will be seen that the concentration of 0·9 to 1·0 p.p.m. has been maintained consistently at the three study areas and that the chemically determined figures agree closely with those calculated from the amount of fluoride used and the volume of water pumped.

It will also be noted that the concentrations obtained at the taps in the waterworks (plant tap) are carried throughout the distribution systems without significant change showing that accumulation of fluoride in water pipes or on deposits in water pipes did not occur. The fear which has been expressed of such an accumulation with eventual release, perhaps in high concentration, should be dispelled.

The results obtained on check samples at the laboratory of the Government Chemist, where distillation from perchloric acid preceded the colorimetric procedure, agreed very closely with those obtained by the plant operators at the waterworks using the direct colorimetric method. This points to two conclusions, first that the concentration of interfering ions in the waters of the three study areas was too low to affect the accuracy of the direct method and second that the method used by the unqualified staff at the waterworks was well within their capacity and that they worked carefully and efficiently.

The mean concentration of fluoride given in Table 1 is not the whole story; a variation about this figure arises through temporary shutdown of the fluoridation unit for maintenance. The percentage frequency distribution of the fluoride ion in the drinking water is given in Table 2.

Table 2

Percentage Frequency Distribution of the Fluoride Ion

(a) *Calculated on a daily basis.**

(b) *Chemically determined on samples of water.*

Parts per million F

(a) No. of days (b) No. of samples		0·6 and under	0·7	0·8	0·9	1·0	1·1	1·2
Anglesey	(a) 1766	1	4	25	40	21	8	1
	(b) 4988	1	1	5	24	55	14	—
Kilmarnock	(a) 1778	2	6	23	24	18	15	12
	(b) 6736	1	2	11	31	39	16	—
Watford	(a) 1752	1	2	8	31	50	7	1
	(b) 9085	1	2	7	41	48	1	—

*In the calculated figures no account has been taken of fluoride naturally present which can vary from a mere trace to 0·1 p.p.m.

It will be noted that the majority of the results of the chemical determinations are in the 0·9—1·1 region, 93 per cent at Anglesey, 86 per cent at Kilmarnock and 90 per cent at Watford.

Concentrations of fluoride greater than 1·2 p.p.m. F. were not encountered and indeed values over 1·0 p.p.m. were not often obtained and then only for short periods during a readjustment of the chemical feed rate. The capacities of the chemical dosing pumps were such that it would have been virtually impossible to obtain concentrations of fluoride much greater than 1·2 p.p.m. F. Concentrations below 0·9 p.p.m. F. occurred at times when the dosing equipment had to be withdrawn from service for normal maintenance or repair, but the equipment has in fact functioned so satisfactorily over the whole 5 years under review without an undue amount of maintenance etc. that the majority of the values below 0·9 p.p.m. F. were in the 0·8 p.p.m. F. region. Values below this level did not occur with sufficient frequency to upset the study.

The Anglesey supply to Holyhead has been omitted from the above tables

because dilution of the fluoridated Gwalchmai water with unfluoridated water occurred. This dilution was deliberate and could not be avoided. The dilution is not constant and so the concentration of the fluoride ion fluctuated, the range over the five years of fluoridation being from 0·1 to 1·0 p.p.m. F. During 1956 and 1957 the fluctuation was so wide that the mean values of 0·6 p.p.m. F. and 0·67 p.p.m. F. respectively are of doubtful use The fluctuation was less marked in the years 1958 to 1960 than in the two preceding years and the mean concentrations p.p.m. F. determined locally are as follows:—

	Mean	*Standard Deviation*
1958	0·70	0·13
1959	0·67	0·12
1960	0·76	0·12

The total frequencies for the period May, 1956 to December, 1960 for the concentration of fluoride in the water supplied to Holyhead are given below:—

p.p.m.	0·1	0·4	0·5	0·6	0·7	0·8	0·9	1·0
	1	62	76	183	274	220	110	4

The mean of this distribution is 0·69 p.p.m. F. with a standard deviation of 0·14 but this distribution is affected by the variable dilution in 1956 and 1957.

APPENDIX 5

Arrangements for the Dental Examinations

(*a*) *The Selection of Children*

The aim was to examine 100 children of each of the ages 3 and 4 years and 100 to 150 school children of each year of age in each area. The number of pre-school children was smaller because difficulties were expected in arranging for their dental examination. Only those children who had lived in the area continuously from birth (with the exception of annual school holidays) were regarded as eligible.

As there is generally no up-to-date list of pre-school children living in a locality this had to be compiled from the birth register, health visitors' record cards and any other available sources. Those children not eligible on grounds of continuous residence were excluded and a sample of a suitable size drawn from the remainder by the use of an appropriate sampling factor. The mothers of selected children were then invited to bring the children to the clinic for examination. If such a procedure did not prove practicable, or did not yield sufficient children, then others attending infant welfare centres, day nurseries or nursery schools were included.

In the Gwalchmai and Bodafon zones of Anglesey all the pre-school children examined were selected from a list compiled as described above and were a reasonably good cross-section of Anglesey children of these ages. But in Holyhead and in Watford and Sutton children attending infant welfare centres, nurseries and nursery schools were included among those examined. Although the children examined in these areas might not be representative of all the children of these ages in the area, they were derived from much the same groups of children each year. In Kilmarnock and Ayr a cross section of children were examined each year together with some children in nurseries and nursery schools but the findings only for the former are presented in this report.

In the Gwalchmai zone some houses did not have a piped water supply, and a few schools also were without a piped supply ; only those children who had piped water both at home and at school were included in the dental examinations. No such restriction was necessary in the Bodafon zone.

In the Gwalchmai and Bodafon areas of Anglesey all eligible school children up to 15 years of age were examined but in Holyhead, only those attending primary and junior schools, that is, up to the age of 11 years, were included. In Watford and Sutton, Kilmarnock and Ayr, representative samples of children were drawn from the school registers. The dental officers in the English and Welsh study areas did not revisit to examine any children absent on the first occasion once they had completed the main examinations in a school, but this was done in the Scottish study.

(b) *The Dental Examinations*

It was planned that the dental examinations should be carried out by a team of full-time and part-time dental officers working under similar conditions in all areas, in schools or in fixed or mobile dental clinics. The same dentists were to carry out the same examinations in each particular pair of study and control areas, and during the time when the examinations were in progress the dentists were to spend alternate weeks in study and control areas. A special course on the method of examination and recording was held for all those taking part in

the study before the examinations began and this was repeated periodically throughout the study. These arrangements were to ensure as far as possible that the same standards of examination were maintained in the pairs of areas for which the dental findings were to be compared.

This plan has in the main been followed. All the dental examinations in the Gwalchmai and Bodafon zones of Anglesey have been made by one dental officer throughout the whole period of the study. Similarly, those in Holyhead have been made (with the exception of one year) by another dental officer, and those in Kilmarnock and Ayr by the same two dentists each year.

In Watford and Sutton, the dental officers were not all available throughout the study but in 1961 the dental examinations of schoolchildren were arranged precisely as in 1956, with the same dental officers examining the same number of children in various ages in the same schools in both years.

The same difficulties were experienced in arranging the dental examinations of pre-schoolchildren and, in view of this, it was decided to arrange for these examinations to be carried out by the one dental officer who had examined more than half the children in this age group each year. (The results of these examinations presented in this report therefore relate solely to the children examined by this particular dental officer in 1956 and in 1961—see Table 1, Appendix 6.)

The examinations occupied six weeks in Watford and Sutton, ten weeks in Kilmarnock and Ayr, three to four weeks in Holyhead and about fourteen weeks in the remainder of Anglesey where one dental officer carried out all the examinations and where the rural nature of the area presented practical difficulties. The timing of the dental examinations in 1961 was so arranged that a large proportion of 5-year old children then attending school would have lived all or practically all their lives in the study area, which means that those children in the fluoridated areas would have taken fluoridated water from birth or nearly so. This did not necessitate any change in the time of year when the examinations were done in Anglesey or in Kilmarnock and Ayr, but in Sutton and Watford, whereas the examinations had, up to 1961, been done in the summer term, in 1961 they were done in the autumn term.

(c) *Equipment*

Standardised equipment was used in all the study areas. This included portable dental chairs or head-rests, anglepoise lamps or battery head lamps. In the English and Welsh studies, plane mouth mirrors and probes of the Ash's clinic No. 6 pattern were used and to ensure the maintenance of a standard sharp point, specially designed detachable probe heads were introduced, each of these being discarded after use for the examination of six mouths. In the Scottish study, also, similar equipment was used in both areas, including Ash's No. 54 probes.

(d) *Method of Examination and Criteria for the Assessment of Caries*

The method of examination and the criteria for the assessment of caries were the same in all the study and control areas. No abnormality was reported as carious unless it was demonstrable beyond the possibility of doubt. Only those lesions where there was a definite breach of the enamel and palpable softening of the underlying dentine were counted as carious: that is, cavities which should be filled and are, therefore, of practical importance. Early enamel lesions, many of which remain indefinitely at this stage, were not included, nor were pits and fissures on occlusal surfaces where softness could not be detected by a probe.

The findings were dictated by dental officers to specially trained recorders who entered the data on diagrammatic dental charts. The exact condition of the mouth was recorded, including each specific tooth which was present, had been lost through caries or had only partially erupted. The site and extent of each carious lesion and filling was noted, showing the surfaces involved, and the depth of penetration of caries. Other conditions also recorded as possibly influencing the incidence of caries were the standard of oral hygiene and the occurrence of gingivitis, with an indication of its severity. Enamel defects, white or stained, which might be confused with fluoride mottling were also noted.

Radiological examinations were carried out in 1958 on 12 year old children in the study and control areas in England and Wales mainly to determine whether or not the use of X-rays would add materially to the value of clinical examinations. These took place almost immediately after the completion of the clinical examination and were confined to the posterior teeth. It was not considered necessary to include the anterior teeth as inter proximal caries there could readily be detected by transillumination on clinical examination. Small carious lesions in the inter proximal surfaces of the pre-molars and molars, on the other hand, might be missed on clinical examination because of difficulty of access to these surfaces. Two " bite-wing " films were used for each child giving a clear picture of the crowns of all the teeth from the posterior surface of the canines to the anterior surface of the second permanent molars. A standardised technique was used for processing the films and these were studied independently by two examiners.

The results obtained in the four areas are shown in Table 6 in Appendix 6. It will be seen that the use of X-rays made little difference to the caries count.

APPENDIX 6

Details of the Dental Findings and comparison with American Findings

The findings from the dental examinations for the baseline years and 1961 are given in the tables below. For children aged 3 and 4 years, these findings relate to the full deciduous dentition but for children aged 5 to 7 years they relate to the deciduous canines and molars only because any assessment of the extent of caries in the later years is affected by the shedding of the deciduous incisors. In the analysis of the dental data any teeth missing in children aged 3 and 4 years and any missing canines and molars in children aged 5 to 7 years were assumed to have been lost through caries. The criteria used in comparing the dental condition of children in the control and study areas are (1) the average number of decayed missing and filled (dmf) teeth per child termed "carious teeth" in this Report. (2) the percentage of children free from caries and (3) the percentage of children with 10 or more carious teeth.

The numbers of children examined in each study and control area in the baseline period and in 1961 are shown in Table 1. Table 2 shows for children aged 3 and 4 years in each area the average number of carious teeth per child, the percentage of children free from caries and the percentage of children with 10 or more carious teeth. Table 3 gives the same information for children aged 5, 6 and 7 years.

It is clear from Tables 2 and 3 that in the study areas there was among children aged 3—5 years a substantial reduction in the average number of carious teeth per child and some reduction, also, among those aged 6 and 7 years. Similarly, there were substantial increases in the study areas in the proportion of children free from caries and reductions in the number of children with 10 or more carious teeth. There were however changes over the study period in dental condition in some of the control areas. Such changes are likely, at least in part, to have been due to changes in various factors which affect dental health, for example, diet or oral hygiene. It is possible that there were similar changes in these other factors in the study areas, and allowance has been made for this in assessing the true effects of fluoridation.

This allowance was made by adjusting the findings in the study areas on the basis that the same changes occurred in the period in those areas, due to these other factors, as occurred in the respective control areas. The results after adjustment are given in the following Table.

Changes Between the Baseline Years and 1961 *in the Study Areas after Adjustment*

Children aged 3 *to* 7 *years*

Percentage Reduction in the Average Number of Carious Teeth per Child

Study Area	Children Aged:				
	3 years*	4 years*	5 years†	6 years†	7 years†
Anglesey, Gwalchmai Zone	68	51	56	25	9
Anglesey, Holyhead	77	51	45	13	12
Watford	73	53	44	25	10
Kilmarnock	55	56	42	24	15

*Full dentition. †Deciduous canines and molars only.

It will be noted from the Tables that there is some similarity in the figures for Holyhead and those for the Gwalchmai zone of Anglesey and the other study areas although the level of fluoride in the Holyhead water was variable. This is of interest but it is too early to draw any conclusions.

No report can as yet be made on any change in the incidence of enamel defects. These usually occur only on permanent teeth and very few of these teeth which have been formed during the five years of fluoridation have yet erupted.

Overall Picture

To obtain an overall picture of the effects of fluoridation the findings for the three control areas in the baseline period have been averaged, also those for 1961. Similarly, the findings for the three study areas (but excluding Holyhead) have been averaged.

Table 4 (a) shows that in the control areas the average number of carious teeth per child at each age fell in the study period; the findings from the study areas were accordingly adjusted (as described above) to make allowance for these changes. The resulting figures are given in the last column of Table 4 (a). Similarly, there was an increase in the control areas over the period of study in the percentage of children free from caries, and a similar adjustment was made to the findings for the study areas. The resulting figures are given in the last column of Table 4 (b). Adjustments were also made for the percentage of children with 10 or more carious teeth and the resulting figures are given in the last column of Table 4 (c).

After five years of fluoridation the extent of dental decay as measured by the average number of carious teeth per child has been reduced among three year old children by about two-thirds, among four year old and five year old children by slightly more than a half and by slightly less than a half respectively and among six year old children by almost a quarter. A small reduction occurred among seven year old children.

At each age the proportion of children free from caries has been substantially increased. As regards the percentage of children with 10 or more carious teeth, there was for children aged 3 to 5 years a reduction of more than four-fifths. In children aged 6 years the reduction was just less than one-half and for children aged 7 years it was about a quarter.

Comparison with American Findings

None of the American or Canadian studies included children aged 3 years ; the only study which included children aged 4 years was that at Grand Rapids. There the baseline studies were made in 1944/45 and fluoride was then added to the water supply at a level of 1 p.p.m. In the control area, Muskegon, the water supply contained less than 0·2 p.p.m. of fluoride until 1951 when fluoride was added to the water supply.

The findings from the Grand Rapids study were presented somewhat differently from those of the present study; in the former missing deciduous teeth were not included as carious, whereas in the present study they were. Despite this difference, comparison can be made for younger children between the two sets of results, and accordingly the findings for children aged 4 and 5 years are given in Table 7. The findings for Grand Rapids are for the year 1951, that is about 6 years after fluoridation, whereas the findings of the present study are after 5–5½ years of fluoridation.

It will be noted that over the study period there was an improvement in dental

condition in Muskegon, this amounting to 12 per cent at the age of 4 years and 23 per cent at the age of 5 years. Accordingly, the findings in Grand Rapids have been adjusted, as described above, to allow for these changes in the control area*. At the age of 4 years the reduction in the number of carious teeth per child was 42 per cent in Grand Rapids and 54 per cent in the present studies. At the age of 5 years there was a 45 per cent reduction in Grand Rapids and 47 per cent in the present studies.

Conclusions

The findings from the studies leave no doubt that fluoridation has brought about a substantial improvement in the dental condition of children in the study areas up to 5 years of age. Those aged 5-7 years also showed some improvement.

All the three and four year old children in the fluoridation areas had had fluoride for the whole of their lives and during the whole period of foetal development. These children are thus likely to have received the full dental benefits of fluoridation and for them no further improvement due to fluoridation can be expected. The majority of the five year old children will have taken fluoridated water only since birth, but few if any during the period of foetal growth. Thus some further improvement at this age is to be expected only when fluoridation has been in operation longer.

No findings have so far been reported from the present study for permanent teeth because too few of them have erupted in young children for a true assessment to be made. However, it can be said that there appears to be some small improvement in the permanent teeth but firm figures can only be derived from longer term studies.

The fact that the findings for younger children from the present study appear to be in line with those from the Grand Rapids study indicates that the longer term effects of fluoridation can be expected to be in line with other studies in due course.

* Such an adjustment was not made in the published reports on the Grand Rapids and Muskegon studies but has been made here to make a true comparison easier between the two studies.

TABLE 1

NUMBER OF CHILDREN AGED 3-7 *YEARS EXAMINED IN THE STUDY AND CONTROL AREAS IN THE BASELINE YEARS AND IN* 1961

Age in Years	ANGLESEY						WATFORD/SUTTON				KILMARNOCK/AYR			
	Bodafon Zone (Control)		Gwalchmai Zone (Study)		Holyhead (Study)		Sutton (Control)		Watford (Study)		Ayr (Control)		Kilmarnock (Study)	
	Baseline 1955 and 1956 combined	1961	Baseline 1955 and 1956 combined	1961	Baseline 1955 and 1956 combined	1961	Baseline 1956	1961	Baseline 1956	1961	Baseline 1956	1961	Baseline 1956	1961
3	146	85	161	69	149	74	44(1)	114	43(1)	110	107	130	97	135
4	210	86	227	83	186	104	47(1)	77	66(1)	110	77	132	112	171
5	256	129	307	123	249	117	110	110	148	148	95	135	81	143
6	331	132	336	118	267	122	127	126	182	182	108	174	98	193
7	346	141	366	154	274	111	121	121	192	191	110	184	120	137

(1) Only the children examined by the dental officer who examined all the 3 and 4 year old children in 1961.

TABLE 2

COMPARISON BETWEEN BASELINE YEARS AND 1961

CHILDREN AGED 3 AND 4 YEARS

DECIDUOUS TEETH—FULL DENTITION

Children Aged 3 Years

Study and Control Areas	Average Number of Carious Teeth per child (dmf)		Percentage of Children free from caries		Percentage of Children with 10 or more carious teeth (dmf)	
	Baseline (1)	1961	Baseline (1)	1961	Baseline (1)	1961
Anglesey						
Bodafon Zone—Control	3·97	4·12	27·3	37·6	11·0	20·0
Gwalchmai Zone—Study	3·87	1·26	29·3	59·4	12·5	1·5
Holyhead Zone—Study	3·85	0·92	28·1	68·9	12·5	Nil
Sutton and Watford						
Sutton—Control ..	1·41	1·39	61·3	57·9	4·5	2·6
Watford—Study ..	2·67	0·72	37·2	70·9	9·4	Nil
Ayr and Kilmarnock						
Ayr—Control ..	5·20	4·45	25·2	22·3	27·1	16·9
Kilmarnock—Study ..	4·87	1·88	30·9	51·1	22·7	3·7

Children Aged 4 Years

Study and Control Areas	Average Number of Carious Teeth per child (dmf)		Percentage of Children free from caries		Percentage of Children with 10 or more carious teeth (dmf)	
	Baseline (1)	1961	Baseline (1)	1961	Baseline (1)	1961
Anglesey						
Bodafon Zone—Control	5·83	5·31	14·8	19·8	19·0	21·0
Gwalchmai Zone—Study	5·42	2·42	19·3	43·4	23·8	3·7
Holyhead—Study ..	5·74	2·60	18·6	44·2	21·3	2·9
Sutton and Watford						
Sutton—Control ..	2·55	2·31	34·0	49·4	4·2	6·5
Watford—Study ..	3·64	1·55	34·8	52·7	9·1	1·8
Ayr and Kilmarnock						
Ayr—Control ..	7·16	6·86	13·0	11·4	33·8	29·5
Kilmarnock—Study ..	7·12	2·97	12·5	29·8	31·3	5·3

(1) 1955 and 1956 for the Anglesey areas; 1956 for the other areas.

TABLE 3

COMPARISON BETWEEN THE BASELINE YEARS AND 1961
CHILDREN AGED 5, 6 *AND* 7 *YEARS*
DECIDUOUS TEETH—CANINES AND MOLARS ONLY

Children Aged 5 *Years*

Study and Control Areas	Average Number of Carious Teeth per child (dmf)		Percentage of Children free from caries		Percentage of Children with 10 or more carious teeth (dmf)	
	Baseline (1)	1961	Baseline (1)	1961	Baseline (1)	1961
Anglesey						
Bodafon Zone—Control	5·49	5·70	7·4	7·0	9·7	11·6
Gwalchmai Zone—Study	5·56	2·58	10·1	29·3	13·3	Nil
Holyhead—Study ..	5·39	3·09	10·0	24·8	10·9	1·7
Sutton and Watford						
Sutton—Control ..	4·97	3·58	13·6	25·5	10·0	4·5
Watford—Study ..	5·43	2·17	8·1	43·2	9·5	Nil
Ayr and Kilmarnock						
Ayr—Control ..	6·52	6·89	4·2	3·7	21·1	18·5
Kilmarnock—Study ..	6·44	3·99	6·2	20·3	21·0	4·9

Children Aged 6 *Years*

Study and Control Areas	Average Number of Carious Teeth per child (dmf)		Percentage of Children free from caries		Percentage of Children with 10 or more carious teeth (dmf)	
	Baseline (1)	1961	Baseline (1)	1961	Baseline (1)	1961
Anglesey						
Bodafon Zone—Control	6·24	6·06	6·2	6·1	16·9	9·1
Gwalchmai Zone—Study	6·64	4·85	3·8	12·7	18·7	7·6
Holyhead—Study ..	6·04	5·05	5·6	9·0	13·1	6·6
Sutton and Watford ..						
Sutton—Control ..	5·44	4·49	10·2	17·5	11·0	5·6
Watford—Study ..	5·65	3·52	8·8	23·1	12·1	2·7
Ayr and Kilmarnock						
Ayr—Control ..	7·29	8·11	0·9	1·7	21·3	31·0
Kilmarnock—Study ..	7·19	6·05	6·1	6·2	21·4	16·1

(1) 1955 and 1956 for the Anglesey areas; 1956 for the other areas.

TABLE 3—continued

Children Aged 7 Years

Study and Control Areas	Average Number of Carious Teeth per child (dmf)		Percentage of Children free from caries		Percentage of Children with 10 or more carious teeth (dmf)	
	Baseline (1)	1961	Baseline (1)	1961	Baseline (1)	1961
Anglesey						
Bodafon Zone—Control	7·27	7·08	4·3	4·3	25·2	24·1
Gwalchmai Zone—Study	6·91	6·10	3·0	6·5	21·5	16·2
Holyhead—Study ..	6·83	5·81	2·2	7·2	20·1	13·6
Sutton and Watford						
Sutton—Control ..	6·00	5·15	5·8	10·7	12·4	7·4
Watford—Study ..	6·42	4·95	7·3	15·2	13·5	7·3
Ayr and Kilmarnock						
Ayr—Control ..	7·96	8·45	2·7	1·1	30·0	34·8
Kilmarnock—Study ..	7·85	7·09	1·7	1·5	29·2	22·6

(1) 1955 and 1956 for the Anglesey areas; 1956 for the other areas.

TABLE 4 (a), (b) *and* (c)

CHANGES IN THE THREE STUDY AND THREE CONTROL AREAS COMBINED

(a) *Average Number of Carious Teeth per Child*

Children Aged:	Study Areas			Control Areas			Adjusted** percentage reduction in study areas
	Average number of carious teeth per child (dmf)		Percentage Reduction	Average number of carious teeth per child (dmf)		Percentage Reduction	
	Baseline	1961		Baseline	1961		
3 years*	3·80	1·29	66	3·53	3·32	6	64
4 years*	5·39	2·31	57	5·18	4·83	7	54
5 years†	5·81	2·91	50	5·66	5·39	5	47
6 years†	6·49	4·81	26	6·32	6·22	2	24
7 years†	7·06	6·05	14	7·08	6·89	3	11

(b) *Percentage of Children free from Caries*

Children Aged:	Study Areas			Control Areas			Adjusted** percentage increase in study areas
	Percentage of Children free from Caries		Percentage Increase	Percentage of Children free from Caries		Percentage Increase	
	Baseline	1961		Baseline	1961		
3 years*	32·5	60·5	86	37·9	39·3	4	79
4 years*	22·2	42·0	89	20·6	26·9	31	44
5 years†	8·1	30·9	281	8·4	12·1	44	165
6 years†	6·2	14·0	126	5·8	8·4	45	56
7 years†	4·0	7·7	93	4·8	5·4	26	53

* Full dentition.

† Deciduous canines and molars only.

** That is, after adjustment for the change in the control areas.

TABLE 4—continued

(c) *Percentage of Children with 10 or more Carious Teeth*

Children Aged:	Study Areas			Control Areas			Adjusted** percentage reduction in study areas
	Percentage of Children with 10 or more carious teeth (dmf)		Percentage Reduction	Percentage of Children with 10 or more carious teeth (dmf)		Percentage Reduction	
	Baseline	1961		Baseline	1961		
3 years*	14·9	1·7	89	14·2	13·2	7	88
4 years*	21·4	3·6	83	19·0	19·0	Nil	83
5 years†	14·6	1·6	89	13·6	11·5	15	87
6 years†	17·4	8·8	49	16·4	15·2	7	45
7 years†	21·4	15·4	28	22·5	22·1	2	27

* Full dentition.

† Deciduous canines and molars only.

** That is, after adjustment for the change in the control areas.

TABLE 5

COMPARISON BETWEEN THE FINDINGS IN GREAT BRITAIN AND THE UNITED STATES (GRAND RAPIDS) STUDIES

	UNITED STATES							GREAT BRITAIN
	GRAND RAPIDS (STUDY)			MUSKEGON (CONTROL)			GRAND RAPIDS ADJUSTED PERCENTAGE REDUCTION	COMBINED STUDY AREAS ADJUSTED PERCENTAGE REDUCTION (dmf TEETH)
	Average number of def (1) teeth per child			Average number of def (1) teeth per child				
	Baseline 1944/5	1951	Percentage Reduction	Baseline 1944/5	1951	Percentage Reduction		
Children Aged Four years (2)	4 ·19	2 ·13	49	5 ·05	4 ·46	12	42	54
Children Aged Five years (3)	5 ·37	2 ·27	58	6 ·82	5 ·25	23	45	47

(1) def — decayed, indicated for extraction and filled teeth. Missing teeth were not included.
(2) In all the studies the full dentition was included at this age.
(3) In the Great Britain studies only the canines and molars were included.

TABLE 6

RESULTS OF CLINICAL AND X-RAY EXAMINATION OF POSTERIOR TEETH OF CHILDREN AGED 12 YEARS

	Anglesey		Watford	Sutton
	Gwalchmai Zone	Bodafon Zone		
Number of children examined	69	64	33	71
Average DMF per child				
clinical examination only	4·6	4·6	5·1	4·5
clinical + X-ray	4·7	4·8	5·2	4·6
Difference in DMF per child	0·1	0·2	0·1	0·1

APPENDIX 7

Results in North American Studies after Nine Years or More of Fluoridation

The diagrams below give some of the results after nine years and more of fluoridation in studies carried out in North America.

Figure 1 shows the change in caries incidence in the permanent teeth of children in Grand Rapids, Michigan, where fluoride has been added to the water, to a concentration of 1·0–1·2 p.p.m. since 1945. It will be seen that among children up to ten years of age, who had had fluoride for the whole of their lives, caries was reduced by more than 50 per cent and that the incidence of caries in these age groups was practically the same as in the town of Aurora where fluoride occurs naturally at the same concentration.

It was not only in the Grand Rapids study that this result was observed. Figure 2 shows a reduction in caries of the same order in two other major studies at Newburgh, New York, and Brantford, Ontario, after the same period of time. The consistency of these results—and of all others so far reported in the United States and elsewhere—is the most convincing proof of the effectiveness of fluoridation.

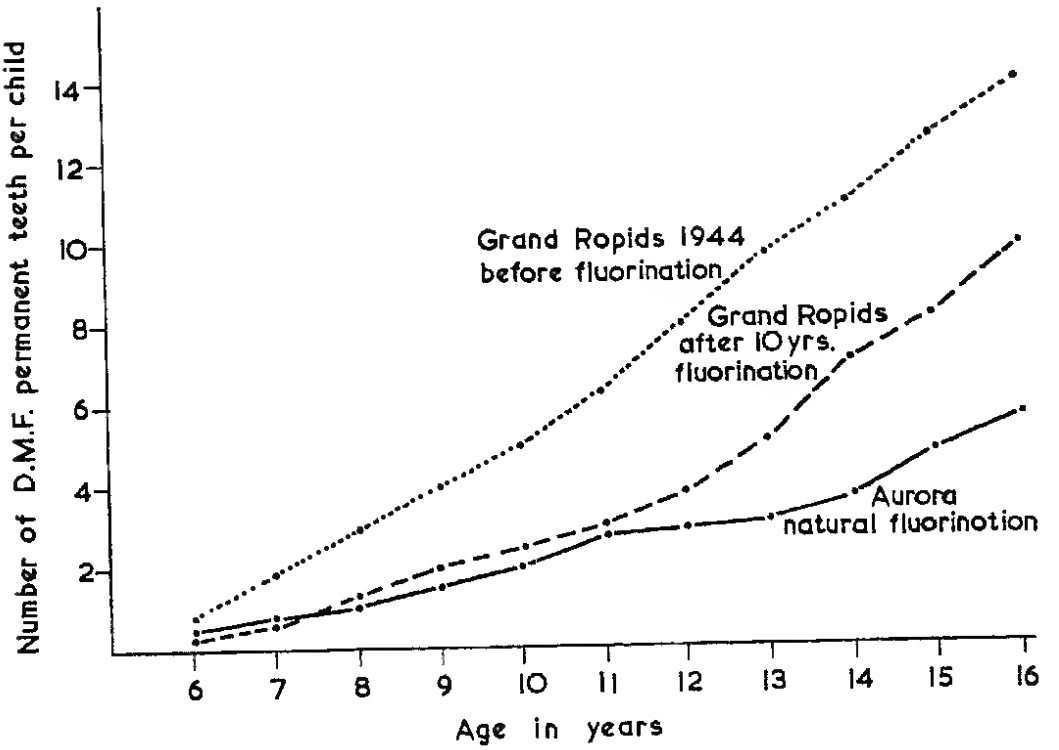


Figure 1. Average number of decayed, missing, and filled (DMF) permanent teeth per child, after ten years fluoridation at Grand Rapids as compared to Aurora (naturally fluoridated). (From New Zealand report of inquiry on The Fluoridation of Public Water Supplies, p. 177, 1957. Adapted from Arnold, F. A., J. Tennessee D. A. 35:126, 1955).

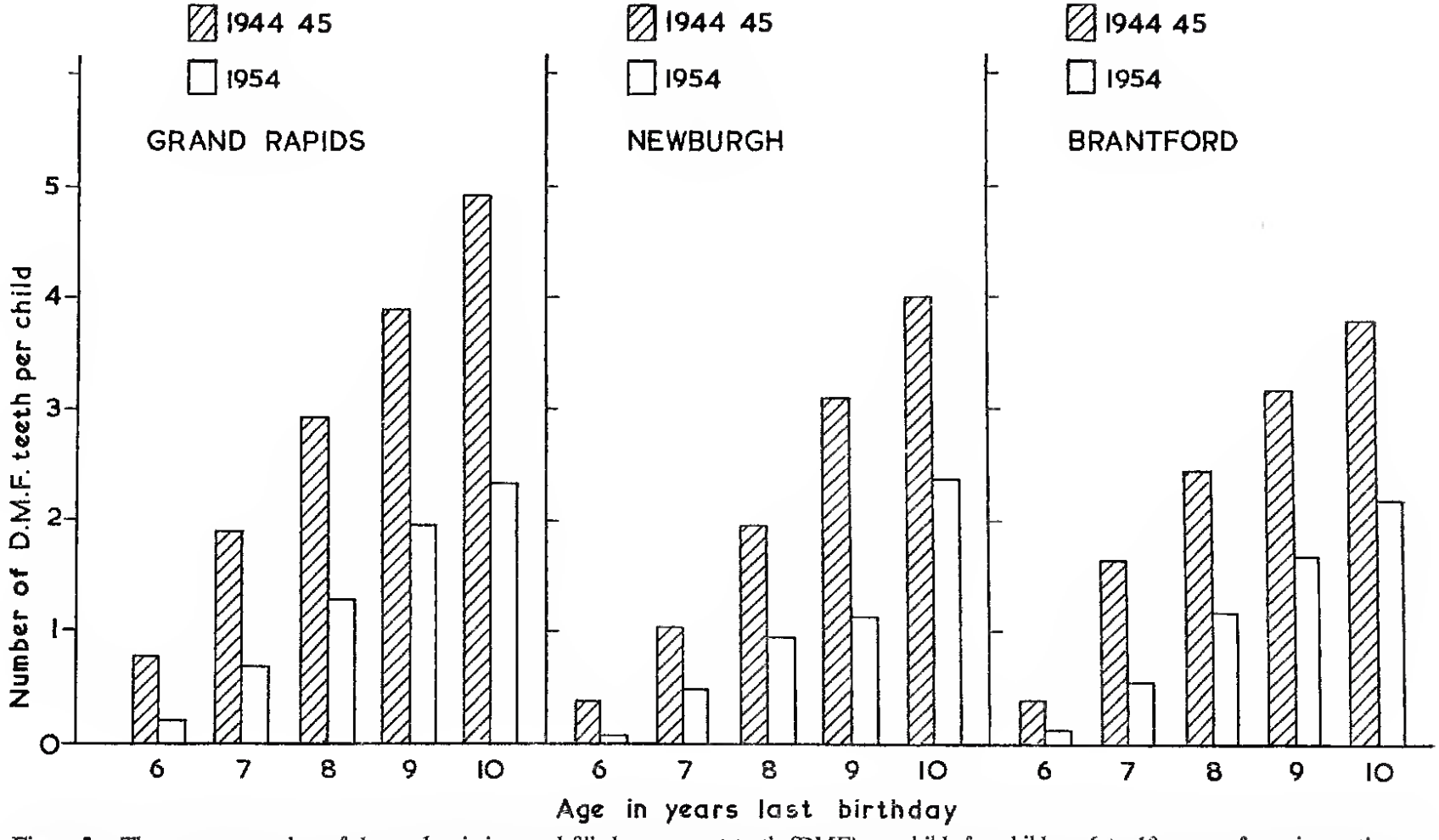


Figure 2. The average number of decayed, missing, and filled permanent teeth (DMF) per child, for children 6 to 10 years of age in continuous residence at Grand Rapids, Michigan; Newburgh, New York; and Brantford, Ontario before (1944-45) and after (1953-54) approximately ten years of controlled water fluoridation. (Compiled from data by: Arnold, F. A., Jr., Int. Dent. J., 7:54, 1957, Dean, H. T., J. Amer. Dent. Assoc. 52:1, 1956; and Hutton et al, Can. J. Pub. Health 47:89, 1956).

APPENDIX 8

SAFETY OF FLUORIDATION

Investigations in Great Britain

Reasons have been given in Chapter III for the adoption of a programme of medical vigilance in the study areas combined with investigation of specific hypotheses or allegations of harm, and for the setting up of the Research Committee, whose findings are outlined in this Appendix.

A three-fold approach was made:—

I—To General Practitioners

The doctors practising in the study areas could find no evidence of harm

Every general practitioner in each of the three fluoridation study areas was asked at intervals throughout the five year period during which the dental examinations were performed for information as to any harm arising out of fluoridation. General practitioners are well placed to detect certain forms of harm arising out of an environmental change such as fluoridation. By virtue of long experience most of them are familiar with the pattern and course of disease in their practices, and the fact that, in many instances, some of their patients live within and some outside the fluoridated area provides them with opportunities to draw comparisons between the two.

From 89 doctors repeatedly questioned in the three study areas, only one reply was received which called for investigation. This was from an obstetrician who enquired whether anaemia of pregnancy was becoming more prevalent. Investigations by Griffith, (1962) the Medical Officer of Health of the area, into this possibility showed that the incidence of anaemia was not related to the water supply.

Had any individual been thought by his doctor to be suffering from ill-health as a result of fluoridation it would have been desirable, provided that he and his doctor consented, to investigate his condition more closely. It had therefore been arranged that the services of a consultant physician would be available followed, if necessary, by hospital accommodation under the National Health Service. But the appointed consultant still awaits his first case.

II—Through Vital Statistics

No indication that fluoride, at the levels encountered naturally in British waters, has any effect on mortality was given by a study of vital statistics.

Major water authorities in the country were asked for information as to the natural fluoride content of the water supplied by them. It was thus possible to identify certain local authority areas wherein all or most of the water contained fluoride in amounts of 0·4 – 5·8 p.p.m. or more and for which mortality statistics are available from the General Register Office. Comparison was then made between death rates from major causes of death in these and the same rates in matched areas where the water contained less than 0·2 p.p.m.

III—By Specific Investigations

The specific investigations made by the Ministry of Health, by public health authorities, and by other investigators in this country, since the publication of

the Mission's report in 1953, are described in this section. In some instances when a hypothesis could be tested with greater certainty in areas where water with a fluoride content naturally above 1 p.p.m. had been consumed for a considerable time this has been done.

(i) *Osteochondritis juvenalis of the spine*

No causal role of fluoride was found

Kemp, Murray and Wilson (1942), Kemp and Wilson, (1947) and Kemp, Wilson and Emrys-Roberts (1948) suggested on evidence which they clearly regarded as preliminary in character that fluoride, particularly in association with malnutrition, might play a part in the production of *osteochondritis juvenalis* of the spine. This possibility was tested by Eley, Kemp, Kerley and Berry (1957) ; X-ray films of the dorso-lumbar spine of 680 children from high and low fluoride areas were read " blind " by independent observers. No evidence was found to suggest that fluoride is in any way associated with *osteochondritis juvenalis* of the spine, in this country. (In the course of the same study, Dr. Kemp also compared the incidence in the spinal x-rays of other bone abnormalities and assessed the stage of epiphyseal development. No effect of fluoride was observed.)

(ii) *Accumulation of fluoride in bone*

No reason was found to expect harmful accumulation of fluoride in bone as a result of fluoridation.

It is accepted that prolonged and very high intakes of fluoride by adults may lead to changes in the appearance or structure of bone. Jackson and Weidmann (1958) working at Leeds University determined the fluoride content of bones of persons coming to autopsy in Leeds, South Shields, and West Hartlepool, where the fluoride contents of the water supplies were less than 0·5, and 0·8 and 1·9 p.p.m. respectively*. These authors found that in all three areas the fluorine content in bone increased fairly steadily with age up to 55 years; a plateau effect then occurred at a level related to the level of fluoride in the water. They concluded that " the artificial fluoridation of drinking water does not enable bone to accumulate fluorine to the level that is considered toxic ". (Although this investigation was not initiated by the Ministry, it is mentioned here as work done in this country during the period with which this report is concerned. Account was taken of it in considering the Ministry's programme of study).

(iii) *Malnutrition and Dental Mottling*

No evidence was found in Britain that malnutrition in conjunction with fluoride caused dental mottling.

There have been reports, such as those by Pandit and Rao (1936) and Massler and Schour (1952), to the effect that, where the diet is inadequate, mottling of teeth may occur with intakes of fluoride that might not have caused mottling among well-nourished persons. These reports relate to malnutrition of a kind or degree which would not normally be encountered in Britain. However, Kemp, Wilson and Emrys-Roberts (1948) appear to have applied these observations to their findings in this country. They write " The fact that some 46 boys

* The value for South Shields has fallen since Drs. Jackson and Weidmann made their study and reported these figures.

had definite signs of dental fluorosis is . . . . evidence that these boys had in the past incurred some degree of malnutrition, for it has been shown that characteristic mottling of the teeth is due to a high fluoride intake accompanied by malnutrition ; in a fluoride area the well-nourished children do not show such changes." A study was made, therefore, in natural high-fluoride areas of possible relationships between mottled enamel and malnutrition in British schoolchildren. The findings have been published by Adcock, Berry and Forrest (1958). No indication emerged that malnutrition of the limited degree observed in the previous decade was associated with increased dental mottling.

(iv) *Mongolism*

The incidence of mongol births in Britain was found to be unrelated to fluoride levels in water.

Rapaport (1956 and 1959) reported that in towns and cities in four American States there was a positive relationship between the proportion of mongol births and the fluoride content of the water supply. Berry (1958), who investigated the incidence of mongol births in South Shields, West Hartlepool, the high fluoride part of Slough and suitably matched low-fluoride areas, obtained no confirmation of Rapaport's findings.

(v) *Peptic Ulcer*

No increase in the number of perforations of peptic ulcer was observed following fluoridation in a study area.

To test the hypothesis that the consumption of fluoridated water might predispose to the formation of, or exacerbate, peptic ulcers, the Medical Officer of Health of Kilmarnock, one of the study areas, compared the number of perforations (this being virtually unaffected by possible differences in diagnostic procedure) before and after fluoridation of the town's water supply. In the five years before fluoridation 65 males and 7 females with perforated ulcer were admitted to hospital. In the subsequent five years the figures were 52 males and 5 females. In the control town of Ayr the corresponding figures were 71 males and 8 females and 58 males and 9 females. It was therefore concluded that, in Kilmarnock, perforation of peptic ulcers was unrelated to fluoridation.

(vi) *Absenteeism from school*

No effect of fluoridation was observed upon absenteeism from school in a study area.

The County Medical Officer of Health of Anglesey examined the school attendance record of children in the county which includes both " study " and " control " areas. The results, which relate to all causes of school absence (i.e. medical and non-medical), have been published by Griffith (1961). The conclusion was that there was no association between fluoride intake and absence rate when considered either according to season or according to length of exposure.

(B) REVIEW OF EVIDENCE

In this section the work done in this country is reviewed together with the more important of that done elsewhere.

In 1958 an Expert Committee of the World Health Organisation reviewed evidence from countries throughout the world and concluded that the safety of

fluoridation had been established. Much of the burden of medical proof in this connection has been borne by workers in the United States of America.

I—Information From Medical Practitioners

The absence of reports of harm from doctors practising in the study areas is in keeping with experience elsewhere.

The absence of reports of harm from the doctors practising in the study areas is in keeping with general experience both in artificially fluoridated areas abroad and from communities here and elsewhere supplied with water containing, naturally, about one part per million of fluoride.

These findings have been considered in relation to that of Waldbott, a specialist in allergic diseases practising in Detroit, who suggested (1956, 1958) that a syndrome including backache, numbness, pain in the legs and arms, gastro-intestinal disturbances, stomatitis, visual disturbances, and malaise and mental deterioration may be due to fluoride in food and water. He also reported urticaria, and in one instance tetaniform convulsions in relation to fluoride. But Dr. Waldbott did not accept offers made by recognised health organisations to investigate his claims. In 1957 he submitted his evidence to the Councils on Foods and Nutrition and on Drugs of the American Medical Association, but failed to convince them that drinking water containing 1 p.p.m. of fluoride was a hazard to health. The Committee appointed to enquire into and report upon the fluoridation of municipal water supplies of Ontario (Report 1961) examined Dr. Waldbott as a witness in public hearing and concluded that the many signs and symptoms described by him were not related to the ingestion of fluoride at about 1 p.p.m. in drinking water or food.

II—Vital Statistics

The British vital statistics confirm those of the United States of America in indicating no adverse effect attributable to fluoride in water.

Vital statistics alone can never provide a complete answer to the question whether fluoride can affect health.

Hagan, Pasternack and Scholz (1954) reported an investigation in the U.S.A. designed to show whether an association existed between various causes of mortality and the presence of natural fluoride in public water supplies ; 32 cities, each having a population of 10,000 or more and each having 0·7 or more p.p.m. fluoride in their water supplies, were paired with nearby towns which had less than 0·25 p.p.m. fluoride in their waters. Deaths from all causes and from heart disease, cancer, intracranial lesions, nephritis, and cirrhosis of the liver were investigated but no statistically significant differences were found between the mortality of " fluoride " and " non-fluoride " towns.

The results of the analysis of data from British local authority areas by Heasman and Martin (1962) are in keeping with the above in that there is no statistically significant higher mortality rate in areas with naturally occurring fluoride in respect of any of the causes of death investigated in both U.S.A. and Great Britain. It is notable that in the British figures the overall mortality is practically the same in both groups of areas. Mortality from certain diseases was higher in some areas with naturally occurring fluoride in their water supplies. But with other diseases the rates were lower. Heasman and Martin found no reason to believe that these variations are due to fluoride.

A very large number of investigations have been made into many hypotheses or allegations in various parts of the world. It is convenient to consider these by age-groups:—

(i) *Before Birth*

There is no convincing evidence of harm from fluoride in the water supply at this stage of life.

As already stated, Rapaport (1956 and 1959) in the United States of America and Berry (1958) in Great Britain reported contradictory findings in relation to mongolism. One of Rapaport's papers (1959) was published after that of Berry and, therefore, possible reasons for the different findings are discussed below.

Rapaport observed a much lower incidence of mongolism than Berry in both high and low-fluoride areas and he suggested that this difference was due to the consumption of tea, which, in Britain, undoubtedly contributes an appreciable amount of fluoride to the diet even in low-fluoride areas. Against this contention it may be noted that figures given by Penrose (1961), for the incidence of mongolism in countries such as Switzerland and Denmark, where tea is not the national drink, are of the same order as those of Britain. Further, it may be noted that other figures for mongolism in the U.S.A., also given by Penrose (1961), are similar to those given in Britain, Denmark and Switzerland, being 500 to 200 or more per cent higher than the upper and lower ranges recorded by Rapaport. The great difficulty in retrospective enquiries into the incidence of mongolism is to ensure that all mongols born in the area under investigation have been traced. Rapaport's data are open to the interpretation that he failed to find all the mongols in high fluoride areas and was even less successful in low fluoride areas.

No reports were received from doctors in the study areas to suggest harm arising to the child *in utero*, and the vital statistics of this and other countries do not suggest an effect of fluoride upon still-birth or neo-natal death rates.

(ii) *In Infancy*

Fluoride in drinking water causes no harm to bottle-fed babies.

In infancy the intake of fluoride, weight for weight, may be higher than at any other time in life through the use of fluoridated water to reconstitute dried milk. Nevertheless, no harm in infants was observed by the medical practitioners in the study areas, and none has been reported by paediatricians and doctors in naturally high-fluoride areas in this country and abroad. Moreover the vital statistics of this and other countries indicate no effect of fluoride on infant mortality.

Mottling of deciduous teeth, which are partly calcified during the first year of life, is always less common than it is in permanent teeth. Weaver (1950) reported four cases of mottled deciduous teeth in 500 children from West Hartlepool (2.0 p.p.m.) and Forrest, Parfitt and Bransby (1951) found no fluorotic mottling in 434 children aged 3 – 4 years in Colchester (1·45 p.p.m.), South Shields (0·8 p.p.m.) and Slough (0·9 p.p.m.). Many of these children must have been reared on bottle feeds of milk reconstituted with water containing fluoride.

(iii) *Childhood*

Very full studies in the United States of America revealed no harm due to fluoride in water.

In 1946-1955 a comparison was made of 817 children aged 0-9 years in Newburgh, U.S.A., where the water was artifically fluoridated, and 711 children of comparable ages in the control town of Kingston. At the end of the ten year study period 500 Newburgh children and 405 Kingston children were available for their final examination. An annual medical examination, supplemented by laboratory and X-ray studies, made by Schlesinger and others (1956) failed to reveal either clinically significant differences, or any effect upon the rate of growth.

In the course of the same study at Newburgh and Kingston, an investigation was made with the object of detecting urinary abnormalities among school-children. Schlesinger, Overton and Chase (1956) reported in this connection that the difference found in the results from the groups in the two cities tended to favour Newburgh children (i.e. those in the fluoridated area.)

McCauley and McClure (1954) found that fluoride in water, even when present in amounts from 3 to 6 p.p.m. had no accelerative effect upon the ages at which ossification of the epiphyses occurs.

(iv) *Adult Life*

(a) **Adults ingesting large amounts of fluoride for long periods have been found to develop definite bone changes. Apart from this, ill effects appear only to follow very high intakes of fluoride such as those associated in the past with special industrial hazards.**

Workers in certain industrial occupations have occasionally been exposed to considerably heavier intakes of fluoride than are likely to occur from the fluoride content of water supplies. Detailed medical information is available on two such groups. The effects of prolonged and heavy exposure to cryolite dust in a group of workers in Denmark were studied by Roholm (1937) and, in Scotland, the Medical Research Council (1949) investigated the health of workers at Fort William, some of whom were heavily exposed to dust or fumes containing fluoride.

In Roholm's study complaints of gastro-intestinal disorder, cough, headache and tiredness were fairly common and lung changes were found which were presumably due to the inhalation of the fluoride-containing dust. Gross bone changes were observed radiologically but absenteeism due to sickness scarcely exceeded the average in industry as a whole in Denmark.

In the study at Fort William complaints of cough and digestive disturbances were noted, and abnormal X-ray appearances were seen in the bones of 25·4 per cent of those heavily exposed to fluoride as compared with 4 per cent among those less heavily exposed. In a summary of the clinical findings given in the report of the investigation, it is stated that there was very little evidence of organic disease of a general nature and still less of abnormal physical signs.

In comparison with these heavy occupational exposures to fluoride the residents of Bartlett, U.S.A., where the drinking water contained 7·8 p.p.m. of fluoride, and who were estimated to have a fluoride intake of rather less than half that of the Danish cryolite workers, have been the subject of a study by Leone and others (1954) who used residents in the nearby town of Cameron which had a water supply containing 0·4 p.p.m. fluoride as controls. In this

study a group of 96 long term residents in Bartlett and 113 in Cameron were examined on two occasions at an interval of ten years.

Leone, Stevenson and others (1955) found that dental fluorosis and bone changes such as increased density and coarsened trabeculation were more prevalent in Bartlett residents than in those of Cameron to the extent that ten to fifteen per cent of those examined at Bartlett had X-ray evidence of bone change of which they said, however, " none approached the extent and degree of change described by Roholm and others ". On the other hand the incidence of cardiovascular disorders in the Bartlett residents was significantly lower than in those of Cameron and laboratory investigations of blood and urine did not reveal any ill effects of fluoride.

Fluorotic bone changes have not been diagnosed in Great Britain except in industrial workers, as at Fort William, or in persons formerly resident abroad.

(b) **The fluoride content of food, tea and other beverages is insufficient to have any ill effect in areas where water contains 1 p.p.m. fluoride.**

Longwell (1957) has published data on the intake of fluoride from food, tea and other beverages. Tea is the principal source of fluoride in the usual diet in this country. A freshly prepared infusion contains about 1 p.p.m. and the fluoride intake of heavy tea drinkers may, therefore, be above the average level of the areas where they live. It has been estimated, however, that a person living in an area where the fluoride content of the water was 1 p.p.m. would have to consume roughly a gallon of tea (30 cups) daily to reach a fluoride intake approaching the average of the residents of Bartlett U.S.A. Moreover, this calculation, which assumes that the average fluid consumption at Bartlett is the same as in Great Britain, is probably an underestimate because Bartlett is situated on latitude 30° North and therefore has a warmer climate than that of Great Britain. It is thus reasonable to believe that the fluoride intake of even the heaviest tea drinkers in areas of Great Britain with water fluoridated at 1 p.p.m. would be unlikely to equal the average intake of the residents of Bartlett, where no harmful effects could be detected.

(c) **The inhabitants of very hot areas of the world drinking water with a high fluoride content may develop kidney disease, but there is no evidence that it can be caused, in temperate climates, by consuming water with 1 p.p.m. fluoride.**

Animal experiments by Bond and Murray (1952) and also studies of the inhabitants of very hot countries where the drinking water has a very high fluoride content, for example by Siddiqui (1955), show that there are limits to the amount of fluoride that can be excreted by the kidney without harm. The amounts consumed in these areas are, however, very much higher than could ever be involved in the fluoridation of water supplies in this country. As indicated in section III (iii) above, urinary abnormalities in children in Newburgh, U.S.A., where the water was flouridated, were not more frequent than in children in the control town; and in Leone's study (1954) at Bartlett U.S.A., where the water had a high natural fluoride content, the incidence of albuminuria was below that in Cameron which was taken as the control area. There is also an entirely reassuring investigation by McClure (1946) in which the urines of 101 young men from Panhandle U.S.A., where the water contained 2·0 to 5·2 p.p.m., were compared with those of 394 young men from low-fluoride areas and no

REFERENCES

Adcock, E. W., Berry, W. T. C. and Forrest, J. R. (1958) *Mth. Bull. Minist. Hlth. Lab. Serv.*, **17**, 54.

Berry, W. T. C. (1958) *Amer. J. ment. Defic.*, **62**, 634.

Bond, A. M. and Murray, M. M. (1952) *Brit. J. exp. Path.*, **33**, 168.

Durbin, P. W. (1955) *J. dent. Res.*, **33**, 789.

Eley, A. J., Kemp, F. H., Kerley, P. J. and Berry, W. T. C. (1957) *Lancet*, ii, 712.

Committee appointed to enquire into and report upon the Fluoridation of Municipal Water Supplies, Ontario (1961) *Report.*

Ericsson, Y. and Ullberg, S. (1958) *Acta odont. scand.*, **16**, 363.

Forrest, J. R., Parfitt, G. J. and Bransby, E. R. (1951) *Mth. Bull. Minist. Hlth. Lab. Serv.*, **10**, 104.

Frada, G. and Mentesana, G. (1953) *Boll. Soc. ital. Biol. sper.*, **29**, 750.

Galletti, P., Held, H. R., Korrodi, H. and Wegmann, T. (1955) *Schweiz, Mschr. Zahnheilk*, **65**, 753.

Griffith, G. W. (1961) *Med. Offr.*, **106**, 393.

Griffith, G. W. (1962) *in preparation.*

Hagan, T. L., Pasternack, M. and Scholz, G. C. (1954) *Publ. Hlth. Rep.*, 69, 450.

Heasman, M. A. and Martin, A. E. (1962) (*in preparation*).

Jackson, D. and Weidmann, S. M. (1958) *J. Path. Bact.*, **76**, 451.

Kemp, F. H., Murray, M. M. and Wilson, D. C. (1942) *Lancet*, ii, 93.

Kemp, F. H. and Wilson, D. C. (1947) *Brit. J. Radiol*, **20**, 410.

Kemp, F. H., Wilson, D. C. and Emrys-Roberts, E. (1948) *Brit. J. soc. Med*, **2**, 66.

Khan, Y. M. and Wig, K. L. (1945) *Indian med. Gaz.*, **80**, 429.

Leone, N. C., Shimkin, M. B., Arnold, F. A., Stevenson, C. A., Zimmermann, E. R., Geiser, P. B. and Lieberman, J. E. (1954) *Medical aspects of excessive fluoride in a water supply: a ten-year study.* In: *Fluoridation as a public health measure*, American Association for the Advancement of Science, Washington. p. 110.

Leone, N. C., Arnold, F. A., Zimmermann, E. R., Geiser, P. B. and Lieberman, J. E. (1955) *J. Amer. dent. Ass.*, **50**, 277.

Linsman, J. F. and McMurray, C. A. (1943) *Radiology*, **40**, 474; **41**, 497.

Longwell, J. (1957) *Roy Soc. Hlth J.*, **77**, 361.

McCauley, H. B. and McClure, F. J., (1954) *Publ. Hlth. Rep.*, **69**, 671.

McClure, F. J. (1946) In: *Dental caries and fluorine*, American Association for the Advancement of Science, Washington. p. 74.

Massler, M. and Schour, I. (1952) *J. Amer. dent. Ass.*, **44**, 156.

Medical Research Council (1949) *Memor. med Res. Coun.* (*Lond.*) **22.**

Murray, M. M., Ryle, J. A., Simpson, B. W. and Wilson, D. C. (1948) *Memor. med. Res. Coun.* (*Lond.*), **18.**

Pandit, C. G. and Rao, N. D. (1936) *J. dent. Res.*, **15**, 281.

Penrose, L. S. and Brown, H. L., editors (1961). *Recent advances in human genetics*, London: Churchill.

Rapaport, I. (1956) *Bull. Acad. nat. Méd.* (*Paris*), **140**, 529.

Rapaport, I. (1959) *ibid*, **143**, 367.

Roholm, K. (1937) *Fluorine intoxication.* London: H. K. Lewis.

Schlesinger, E. R., Overton, D. E., Chase, H. C. and Cantwell, K. T. (1956) *J. Amer. dent. Ass.*, **52**, 296.

Schlesinger, E. R., Overton, D. E. and Chase, H. C. (1956) *J. Amer. med. Ass.*, **160**, 21.

Siddiqui, A. H. (1955) *Brit. med. J.*, ii, 1408.

Smith, F. A., Gardner, D. E., and Hodge, H. C. (1955) *A.M.A. Arch. Industr. Hyg.*, **11**, 2.

Waldbott, G. L. (1956) *Acta med. scand.* **156**, 157.

Waldbott, G. L. (1958) *Int. Arch. Allergy*, **12**, 347.

Weaver, R. (1950) *Brit. dent. J.* **88**, 231.

Wilson, D. C. (1941) *Lancet*, i, 211.

World Health Organization (1958) *W. H. O. Techn. Rep. Ser.*, **146.**

Printed in England under the authority of Her Majesty's Stationery Office
by The Crewe Stationery Co. Ltd., Frances Street, Crewe.

401 Wt. 2552. D. No. 9443. K32. 91268 5/62.